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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 147.

B. T. GALLOWAY, *Chief of Bureau.*

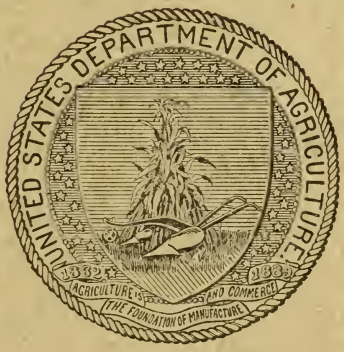
SUPPRESSED AND INTENSIFIED CHARACTERS IN COTTON HYBRIDS.

BY

O. F. COOK,

BIONOMIST, BUREAU OF PLANT INDUSTRY.

ISSUED APRIL 7, 1909.



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BY

O. F. COOK,
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ISSUED APRIL 7, 1909.

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U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 2, 1909.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 147 of the series of this Bureau, the accompanying manuscript, entitled "Suppressed and Intensified Characters in Cotton Hybrids," by Mr. O. F. Cook.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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SUPPRESSED AND INTENSIFIED CHARACTERS IN COTTON HYBRIDS.

INTRODUCTION.

Hybrids produced from two different types of cotton show a wide range of diversity, wider than that of either of the parent stocks. Some of the characteristics of the parent stocks may reappear in the hybrids without any notable change. In other respects the hybrids may be intermediate between the parents, or they may exceed both parents, or they may be more deficient than either parent. Finally, hybrids often show characters which the parental types were not known to possess.

These different kinds of characters of hybrids may be described somewhat more definitely as follows:

Parental characters, inside the normal range of variation of one of the parent groups.

Interparental characters, representing combinations of parental characters or intermediate stages between the characters of the parent groups.

Extraparental characters, not within the parental groups or between them. Of extraparental characters three kinds may be distinguished, as follows:

(1) *Suppressed characters*, representing the deficiency of a parental character or its reduction below either of the parent groups.

(2) *Intensified characters*, attaining a higher expression than in either of the parent groups.

(3) *Primitive characters*, representing the return to expression of characters of remote ancestors no longer brought into expression in the parent groups.

It is not to be supposed that distinct lines can always be drawn between these different kinds of characters, for there are all gradations of expression. Suppressed and intensified characters connect with parental characters on one side and with primitive characters on the other. We may look upon the suppression of a character as a return to an ancestral condition far back in the evolution of the species, before the character was developed. Intensification might also mean the return of a character to an earlier state when it had normally re-

ceived a greater degree of expression. Thus the green color of the fuzz of the seeds of hybrid cottons, which was discussed in a previous report as a primitive character, might also be viewed as an example of intensification.[a]

Further studies of diversity in the Kekchi and Egyptian types of cotton have made it evident that green fuzz occasionally appears in both of the parental types, especially when they are grown under new and unwonted conditions. Several plants with greenish fuzz were found at Falfurrias, Tex., in 1908, in a plot of Kekchi cotton raised from seed newly imported from Guatemala. If hybrids were made from such plants the much more vivid green color of their seeds might be viewed as an intensification of the dull grayish green of the seeds of the parent rather than as a definite recall of a primitive character from a more remote ancestor. Green fuzz appears in our imported Egyptian cotton even more frequently than in the Kekchi, but also in duller shades than in the hybrids. Even when the seeds of Kekchi or Upland hybrids with the Egyptian cotton have no fuzz, a tendency to suppression or intensification of parental characters is still evident, for the seeds are often more completely naked than those of the Egyptian parent, where the ends of the seed commonly have small patches of rather sparse, short fuzz.

SUPPRESSION AND INTENSIFICATION AS PHENOMENA OF HEREDITY.

The phenomenon of suppression of characters is not confined to cotton or to hybrids, but is a general fact of heredity both in natural species and in cultivated varieties. Whenever an ancestral character reappears after a lapse of generations we know that it has continued to be transmitted through the generations in latent or suppressed form. The object of careful selection as applied to domesticated varieties of plants or animals is to suppress their undesirable characters while keeping their desirable characters regularly expressed or intensified. The suppressed characters are not destroyed or entirely eliminated by selection, but continue to be transmitted in latent form. They are likely to reappear at any time, and especially when hybridization or change of external conditions disturbs the internal adjustments that control the development of the plant and determine the expression of the characters.

The idea of intensification of characters, though less familiar than that of suppression, has equal warrant of natural analogy. Evolution itself may be considered as a process of suppressing some characters and of intensifying others; that is, of raising them to higher

[a] Reappearance of a Primitive Character in Cotton Hybrids. Circular 18, Bureau of Plant Industry, U. S. Department of Agriculture. 1908.

degrees of expression. That hybridization has these opposite effects of suppression and intensification may simply mean that it profoundly disturbs the ordinary process of expression, weakening the expression of some characters and strengthening the expression of others.

Suppression and intensification can not be understood, or even considered as possible, if we think of heredity as consisting of the single process of transmission. The facts commonly ascribed to heredity include the results of two distinct processes—transmission and expression. The same character transmitted from the same parental stock to two series of cotton hybrids was in one series entirely suppressed, while in the other series it came into expression in more intensified form. The transmission of a character is not to be judged from its visible presence or absence in any particular individual or series of individuals.

The farther science penetrates into the processes of organic reproduction the more wonderful do they appear, for as yet nothing has been found in the reproductive cells to correspond to the mechanisms required by various theories of transmission. Not only are there no indications of preformed organisms or models of organisms in the protoplasm of the reproductive cells, but all the parts and particles of cells thus far rendered visible to human sense appear to be capable of many changes without any apparent corresponding effect on the final results of heredity. Indistinguishable germ cells may reproduce very diverse organisms, or germ cells which appear to have definite differences may develop into organisms closely alike.

If organisms transmitted to their descendants only the characters that appear in their own bodies we could still continue to suppose that heredity might be explained in some simple mechanical way. But when we take into account the fact that plants and animals inherit from their parents and transmit to their descendants large numbers of peculiarities, or characters, which are not shown in their own bodies the mechanical theories of heredity appear entirely inadequate.

We take it as a matter of course that sons do not resemble the father alone, but may show the traits of the mother's family in the voice, or the beard, or other masculine traits or peculiarities. Yet all such cases are evidences of this general fact regarding heredity which is still left largely out of account, even by special students and writers on the subject—the fact that characters can be transmitted from one generation to another without being brought into expression. Thus the ordinary processes of heredity, as shown in the inheritance of sexual differences, abound in instances of alternations between the suppression and intensification of characters.

The current idea that hybrids represent mere mixtures or combinations of parental characters has also tended to interfere with a recognition of the phenomena of suppression and intensification. The behavior of these cotton hybrids does not comport with the idea that hybridizing or crossing among the members of a species has the effect of hindering or preventing evolution by smoothing down their differences into intermediate averages. Experiments with narrow-bred varieties, like those performed by Mendel, have shown that contrasted parental characters need not combine into an intermediate average, but that one may be dominant over the other and gain exclusive expression, though both characters are transmitted to later generations. These experiments with hybrids between different types of cotton afford excellent instances of another class of facts, showing that hybrid organisms may not merely preserve the features of the parents, but may go farther than either of the parents in the expression of the parental peculiarities.

SUPPRESSION OF BRACTLETS IN HYBRIDS OF UPLAND COTTON.

The most definite illustration of suppression of characters in cotton hybrids was found in a cross between the Kekchi type of cotton from Guatemala and the McCall variety of the United States Upland cotton. Two series of these hybrids were grown at Falfurrias, Tex., in the season of 1907, one a cross of McCall by Kekchi and the other the reciprocal cross, Kekchi by McCall.

No general differences of behavior could be detected between the two lots of hybrids. In size, habit of growth, and other vegetative features they showed a marked resemblance to the Kekchi parent and were all very much alike except two individuals which differed notably from the rest and had an equally definite resemblance to the McCall parent. A close examination of these individuals, to see whether any sign of the Kekchi parentage could be found, showed that they had no bractlets, though these organs are generally well developed in the Kekchi cotton and are usually to be relied upon as distinctive of Kekchi hybrids. But on taking the precaution to verify this supposed presence of bractlets in the other hybrids, where there was a marked predominance of the Kekchi characters, it was found that these also were lacking in bractlets. Every individual was examined, but not a trace of a bractlet was found.

The bractlets are small leaflike organs found inside the involucre which incloses the bud of the cotton plant. When the bractlets are well developed they have somewhat the size and general appearance of the stipules, the two small pointed organs found at the base of each of the ordinary leaves. The presence of bractlets may be considered as a primitive condition, since involucral leaves provided with

stipules must be reckoned as less completely specialized than when the stipules are entirely suppressed.

Many intermediate stages have been found, showing that the three large bracts of the involucre represent as many leaves whose greatly reduced blades are united with their greatly enlarged stipules. There are also many intermediate stages between the bracts and the parts of the inner cup surrounding the bases of the petals. This cup is generally described as the calyx, but may prove to be an inner involucre. Under such an interpretation of the parts it becomes possible to reckon the bractlets as stipules of the bracts which form the inner involucre, corresponding to the 10 or 12 narrow pointed organs which subtend the 5 or 6 lobed inner involucre of the okra plant. The only difference would be that the bractlets of cotton have retained their stipular form much more nearly than those of the okra, and that they do not appear on all the bracts of the inner involucre, but only on those that bear nectaries—those that stand opposite the three openings between the external bracts.

The Kekchi and other related Central American types of cotton have the bractlets larger and more frequently present than in any other kinds thus far known. Among our United States Upland varieties the bractlets are much less frequent than in the Kekchi, but are nearly always to be found by a little persistence in searching. Only in the Old World types of cotton do the bractlets appear to be entirely lacking. Even in the McCall variety bractlets are occasionally present. The complete suppression of the bractlets in the one series of hybrids represents a condition for which no parallel has been found in either of the parent stocks.

Hybrids between the Kekchi cotton and other Upland varieties usually show notable reductions of the bractlets from the Kekchi standard of expression, especially when prolonged dry weather keeps the plants small and compact. Even among the Kekchi plants which have not been hybridized, notable differences may be found in the expression of the bractlets. In some of the selections of small, compact plants bractlets are very scarce, but in all the other hybrids and Kekchi selections bractlets have been found on a very large proportion of the luxuriant, freely branching plants which resemble the McCall-Kekchi hybrids of 1907. These hybrids remain as the only observed instance of a complete lack of bractlets in plants of luxuriant growth.

The only fact which seems to have a possible bearing on this strange occurrence is that the bractlets of the McCall and some of the similar cluster types of cotton appear to be very narrow and slender, more so than in other kinds of Upland cotton. It is possible that a specialized form of the bractlets might not combine readily

with the more primitive form shown in the Kekchi parent and that this incompatibility might lead to the suppression of the bractlets even in plants that showed a preponderance of other Kekchi characters.

INTENSIFICATION OF BRACTLETS IN HYBRIDS OF EGYPTIAN COTTON.

The behavior of the bractlets in hybrids between the Kekchi cotton and the Egyptian is in marked contrast with that shown in the McCall and other Upland hybrids. Instead of the complete suppression of the bractlets or of any general tendency to reduce them below the Kekchi standard, the bractlets show an opposite tendency to exceed those of the Kekchi parent. This is the more notable in view of the fact that the expression of the bractlets among the Sea Island and Egyptian varieties is usually weaker than in the Upland varieties; sometimes there are no bractlets at all in a whole planting.

Yet when these same Sea Island and Egyptian varieties are crossed with the Kekchi the bractlets are often larger and appear with greater regularity than in the Kekchi cotton itself. Hybrid plants have been found with every involucre provided with a full complement of six well-developed bractlets, a degree of regularity which has never been observed in the Kekchi cotton. Single involucres with six bractlets are occasionally found in the Kekchi cotton, but this regularity is not usual even in single flowers, to say nothing of finding it on all the flowers of a plant. Among Upland and Egyptian cottons bractlets commonly appear alone or only two or three in an involucre; an equal pair is a very rare occurrence. The frequency of such pairs distinguishes the Kekchi from the other cottons, but these hybrids go far beyond the pure Kekchi.

Intensification, like suppression, is not equally pronounced in all cases, but is much more notable in some plantings than in others. Bractlets are generally more numerous in the plants that show Kekchi habits of growth and other Kekchi characters than in those that approach more nearly to the Egyptian parent. Nevertheless, bractlets are seldom entirely lacking in any of the hybrids between the Kekchi cotton and the Jannovitch variety of the Egyptian, on which observations have chiefly been made.

Natural conditions which tend to give the plants Kekchi habits of growth tend also to increased expression of the bractlets. The series of hybrids which showed the greatest development of bractlets were second generation plants grown at Falfurrias, Tex., in 1907, in the same field where the hybrids between the Kekchi cotton and the McCall variety of Upland cotton showed a total suppression of bractlets.

INTENSIFICATION OF OTHER CHARACTERS.

Though no other examples of suppression and intensification as striking as those of the bractlets have been found, similar tendencies occur in connection with several other characters, both vegetative and reproductive. The great size and superior vegetative vigor of many of the hybrid plants may be reckoned as phenomena of intensification, for while the largest plants commonly show more resemblance to the Egyptian parent in their habits of growth, they are often twice the size of any of the pure Egyptian plants in the same field, and from five to ten times as large as ordinary Kekchi plants. Even in dry localities where the growth of the plants appears to be checked by lack of water the hybrid plants continue to grow more vigorously than the others and attain much larger proportions.

The leaves of hybrid plants not only show many gradations between the broad lobes of the Kekchi and the narrow lobes of the Egyptian, but occasionally become even narrower than the Egyptian. Nevertheless, it may be that this is not a true instance of intensification, for there are forms of Upland cotton with still narrower lobes than the Egyptian.

The involucral bracts of the hybrids are often larger than those of either parent. Nearly all of the large bracts inherit the cordate shape from the Upland parent. The rounded lower lobes, instead of being reduced and rendered intermediate between the parental forms, are often more pronounced than in the Upland, and afford one of the most reliable marks for distinguishing Upland hybrids from the pure Egyptian plants. The margins of the bracts also afford examples of intensification of the Upland characters, for the teeth are often more numerous and better developed than in the Upland parent. In very rare cases there is a reduction of the teeth to below the Egyptian number. Intensification also appears in the nectaries of the involucre. Some of the hybrid plants have the outer nectaries larger than in either parent and present with greater regularity, for in the parent types involucres are often found in which only two of the bracts have nectaries, and sometimes only one or none at all.

An indication that intensification may also affect the bolls and the number of locks in the bolls of cotton hybrids may also be noted. Several plants notably similar to the Triumph variety of Upland, and probably hybrids of that variety, were found in a Mexican stock at Yuma, Ariz., in 1908. The bolls of these supposed hybrids, while not larger than the parent varieties often produce, were distinctly larger than those produced by either of the parent varieties at Yuma. There were also about three times as many 5-locked bolls as 4 locked, whereas the parent varieties showed at Yuma only about equal numbers of 5-locked and 4-locked bolls. Yet this does

not involve an actual increase of locks beyond the range of the parent types, for under favorable conditions the percentage of 5-locked bolls in Triumph runs about as high as in these supposed hybrids.

Nevertheless, the ability of hybrids to resist the unfavorable conditions and retain the large size and many locked characteristics of the bolls is a matter of practical interest, of which other examples are to be given. That the conditions of the Yuma experiment were really unfavorable was also shown in many other varieties, not only in a general reduction of the size of the bolls and of the numbers of locks, but in the unusually rounded form of the bolls. The length of the lint was also found to be much reduced. There appears to be a very general correlation between the shape of the boll and the length of the lint running through all the varieties of cotton that have been studied with this idea in mind, plants with more rounded bolls having shorter lint.

DETERIORATION OF LINT IN UPLAND HYBRIDS.

Many crosses have been made between the Kekchi cotton and the United States Upland varieties with the object of adding some of the weevil-resisting characters of the Kekchi to the Upland stocks. The utility of these hybrids is still in doubt for the reason that the lint is notably inferior to that of the parent stocks, at least in the earlier generations. This is not a case of complete suppression like that of the bractlets, for the hybrids all have lint. Nor is the lint of the hybrids shorter than in inferior plants of the parent stocks. But if the possession of long lint were to be considered as a separate character there would appear to be a complete suppression, for all the plants of the first hybrid generation have short lint, with great regularity. In the second generation, also, the lint remains short, though not so uniformly so as in the first. In the third generation individual plants have shown marked improvements, proving that the long lint character has only been suppressed, not lost altogether. The short lint of these hybrids might also be reckoned as representing the return of a primitive character to expression, like the green color of the fuzz of the seed which appears in some of the same hybrids and often remains for only one or two generations.

IMPROVEMENT OF LINT IN EGYPTIAN HYBRIDS.

The length of lint shows the same strange divergence of behavior in Egyptian hybrids as did the bractlets, which were suppressed in the Upland hybrids of the Kekchi cotton and intensified in the Egyptian hybrids. Instead of becoming shorter than in either of the parent stocks, the lint of hybrids between Upland types of cotton and

the Egyptian type is longer than in either parent. The strength of the fiber is notably improved, as well as the length.

These favorable reactions seem to be more regular and more pronounced in hybrids between the Egyptian and the Kekchi cottons than when the Egyptian is crossed with United States Upland varieties. The Kekchi hybrids also have an advantage in fertility by reason of the greater length of the lower fruiting branches and in the greater frequency of 5-locked bolls. Very few of the Egyptian-Upland hybrids have 5-locked bolls, and then only in small numbers, whereas the Kekchi hybrids commonly have good proportions of such bolls.

The intensification of the lint characters in the first generation of the Egyptian hybrids of the Kekchi cotton is quite as regular a phenomenon as the deterioration of the lint in the first generation of the Kekchi-Upland hybrids. Though not entirely uniform, of course, the lint of the hybrids has in all cases been distinctly more uniform than that of the parent stocks growing under the same conditions. Only in carefully selected varieties grown under thoroughly accustomed conditions do we find greater uniformity than the hybrid plants have shown. The lint of the hybrids is notably less affected than that of the parent stocks by the diversity which appears during the process of acclimatization. Thus it may be argued that suppression and intensification are definite facts in the heredity of these hybrids—even more definite than the ordinary processes of heredity, which permit a wider range of variation.

Nevertheless, it must not be forgotten that suppression and intensification are definite phenomena only in the first and second generations. They can not be reckoned as permanent qualities of the hybrids, but may be thought of as results of the special conflicts or stresses between divergent tendencies in the early generations of the hybrids. In later generations, when the predominance of one or the other of the parental types becomes more definitely established in the hybrids there is a notable decline in length and strength of the lint. There seems to be a general tendency for the Upland characters to gain the ascendency in the later generations. The lint also shows a notable approximation to that of the Upland type, but commonly falls to the condition of very inferior Upland, as though all the effects of selective improvement of the parent stocks had been lost.

POSSIBILITY OF UTILIZING INTENSIFIED HYBRIDS.

That crosses between Sea Island or Egyptian cotton and varieties of the Upland series often produce lint of very high quality has been known, of course, to all who have made experiments with this group of plants. But whenever attempts were made to utilize this superior-

ity in developing superior hybrid types of cotton the way has been blocked by the facts already stated, that the condition of intensification is not permanent but gives way to diversity and deterioration in the later generations. The tendency to reversion and deterioration is persistent and appears not to yield to the most rigid selection. Individual plants with superior lint continue to appear, but the average rapidly declines far below that of the Egyptian parent, if not below the Upland. The lint of the degenerate hybrids of the later generations is not only short, but is often as remarkable for weakness as that of the early generations is for strength.

The transient character of the phenomenon of intensification shows that it can be utilized only in the first generation of the hybrids, or at most in the first and second generations. To make this possible large quantities of first generation hybrids must be obtained, and by methods less difficult and expensive than hand pollination. In order to be of commercial value whole fields of hybrids would have to be grown. Hybrids are easily obtained by planting Uplands and Egyptians close together and allowing the bees to cross-fertilize the flowers. But hybrids are no advantage when mixed with the parent stocks, in spite of the superiority of their lint, for they interfere with the uniformity requisite in high-grade cotton. They would be of much greater value if kept by themselves.

The study of the hybrids between the Egyptian cotton and the Kekchi suggests a practical way in which this may be done. When the Kekchi cotton is allowed to become crossed with the Egyptian pollen the large, smooth hybrid plants growing among the small, hairy Kekchi plants are very conspicuous, so that it would be easy to pull out the Kekchi plants and leave the field stocked with hybrids alone. The use of Upland varieties for the making of such hybrids may also be practicable, but somewhat more skill may be required to distinguish the young plants in the earlier stages. By planting alternate rows of Kekchi and Egyptian in special seed plots, a large proportion of hybrid seed would be obtained, and with no greater trouble or expense than would be required to maintain an adequate selection of any superior variety of cotton by the methods now used in the production of Sea Island and other high-grade types.

RELATION OF COHERENCE OF CHARACTERS TO INTENSIFICATION.

In hybrids between different types of cotton there is a distinct and very general tendency to coordination or coherence of characters. Notwithstanding the fact that there are large numbers of contrasted differences between the parental types, the hybrids sometimes show only the characters of one parent, by a consistent

suppression of all the diverging tendencies derived from the other parent. Such plants are likely to be somewhat peculiar in comparison with pure-bred individuals of the type they resemble, but without showing any definite departure beyond the range of variation of the parent type. There appears to be a rather definite gap between these hybrids that resemble one parent exclusively and those that show characteristics of both parents. No cases were found where one character of one parent was definitely expressed in a plant otherwise having an exclusive resemblance to the other parent. If an Egyptian-like plant shows one obvious Upland character other Upland characters are always found very definitely indicated, if not fully expressed.

The production of high-grade lint by the hybrids appears to be definitely related to this coherence of characters. Hybrids which resemble only one parent have also the lint character appropriate to that parent. Special excellence of lint and high fertility have been found only in plants that show their hybridity by the definite expression of characters of both parents. In addition to this general tendency for the characters of the same parent to appear together there is a more particular tendency for corresponding or closely associated characters to preserve their coherence. Thus hybrids with pale flowers also have the flowers of the open, cuplike, Upland form instead of the more narrowly tubular form of the Egyptian flower. Incongruities, such as flowers of Upland shape with the darker Egyptian color, are rare and have been found thus far only on plants which are nearly sterile or otherwise definitely degenerate.

Though the experiments have not been carried far enough to afford conclusive evidence, it appears that the tendency of the Egyptian characters to gain exclusive expression in members of the first and second generations gives place in the later generations to an opposite tendency toward the exclusive expression of Kekchi or Upland characters. This increasing potency of the Upland characters in the later generations may be looked upon as the cause of deterioration of the lint, since it puts to an end the condition of mixed expression of characters under which the intensification appears.

INFLUENCE OF EXTERNAL CONDITIONS ON INTENSIFIED HYBRIDS.

In addition to the superiority of their lint, the vegetative vigor of the hybrids gives them a great advantage in the field. They are much more fertile than the parent types, often producing several times as many bolls as adjacent Egyptian plants. A single hybrid plant grown at Yuma in 1907 is reported by Mr. W. A. Peterson to have

borne over 1,100 bolls. Plants with 200 to 300 bolls are frequent. The hybrids also appear to be much less susceptible to injury from adverse conditions, either in the yield or in the quality of the lint. Yet there are notable differences in the behavior of the hybrids in different places, and these differences will need to be taken into account if commercial cultures of hybrids are attempted.

The external conditions are able to affect the yield and the quality of the lint of the hybrids through the coherence of characters described in the previous chapter. The hybrids which resemble only the Egyptian parent in its unacclimatized form and fail to show any definite Kekchi or Upland characters or any improvement of lint have all been found under conditions favoring the development of the tall, erect form in Egyptian plants. In a planting at Coachella, Cal., in 1908, Mr. T. H. Kearney found that the hybrids resembled the pure Egyptian plants much more closely than at Yuma or at Sacaton, Ariz. Neither by the habits of growth nor by the more detailed differences, such as the form and color of the bolls, could the hybrids be recognized with the same readiness as in the Arizona plantings.

Where the external conditions favor the Egyptian habit of growth it is possible to find plants, even in the second generation of hybrids, that show only Egyptian features either in the vegetative parts of the plant or in the seeds and lint. Careful study of such a plant was made at Del Rio, Tex., without finding any of the signs of hybridity which had been very apparent in the parent of this particular plant and had been carefully noted in the preceding year. Other plants in the same row showed many degrees of expression of the Egyptian characters, and there appeared to be a very consistent relation between fertility and superiority of lint, increasing as the non-Egyptian characters came into expression. The conditions of growth were distinctly unfavorable to fertility in Egyptian cotton and the plants appeared to be affected by them to an extent corresponding to the degree of expression of the Egyptian characters. In an adjoining row of Egyptian plants a few individuals that were distinctly more fertile and had better lint than the others also gave distinct evidences of hybridization.

On the other hand, when the conditions definitely favor the expression of Upland or Kekchi characters there is a notable improvement in the yield. Even the second generation of the hybrids may produce excellent, uniform lint, as was shown in the season of 1907 at Falfurrias, Tex., where the vegetative development of the plants was definitely restricted by dry weather and the Kekchi habits of growth and other Kekchi characters were called forth. And even though some of the Kekchi characters are present, the improvement of the

lint may not be very pronounced when the hybrids are raised under conditions of too great humidity so that the plants become crowded together and are obliged to grow tall and spindling and bear no fruit on the lower branches. The lint averages much better on hybrid plants grown in more open situations where they are able to begin bearing while still young.

Relatively dry localities would also be more favorable for the production of hybrid seed, for if the Egyptian plants become too luxuriant they might not begin to blossom until after the Kekchi plants had set most of their crop, so that very few hybrids would be obtained. Dry soils which retard the vegetative growth of the Egyptian plants also incline them to earlier flowering. To secure a maximum of cross-fertilization it might be necessary to plant the Egyptian cotton in advance of the Kekchi.

Breeders and students of heredity will understand from these facts that the behavior of these hybrids between different types of cotton is quite different from what would be expected in Mendelian hybrids between narrow-bred varieties or strains of the same variety. Increased vigor and fertility are commonly found in crosses between narrow strains, the so-called "elementary species" or "biotypes" used in Mendelian experiments, but such crosses of closely related varieties of cotton do not appear to give any such definite phenomena of intensification as do hybrids between widely different types. The characters of such hybrids would be described as parental or interparental, not as extraparental.

In Mendelian hybrids the characters derived from the same parent show no such coherence of expression, but appear in all sorts of combinations with characters of the other parent. This indicates a complete freedom of substitution or alternation in the expression of Mendelian characters. Nor has it been supposed that the Mendelian expression of contrasted parental characters can be affected by differences of external conditions, which have such obvious influences upon these hybrids between the different types of cotton.

OTHER EXAMPLES OF THE INFLUENCE OF EXTERNAL CONDITIONS.

That external conditions have an influence upon the characteristics of plants and animals is a familiar fact, but influences of the sort indicated in the previous chapter are not commonly recognized or taken into account by scientific experimenters and breeders. External conditions may be said to influence expression in three ways, first by hindering or inhibiting expression, second by inducing an accommodation or readjustment of characters to correspond with the change of conditions, and third by throwing the expression of

characters out of adjustment, so that they are changed without reference to better adaptation to the new condition.

Influences of the first kind are seen when lack of heat, light, water, or other conditions or substances needed by the plant keep it from reaching its proper stature or from showing its normal characteristics. The second effect of external conditions is seen in plants that regularly change their characters to adapt themselves to different conditions, as in the amphibious species of the buttercup family, which produce finely divided leaves when they grow in the water, but ordinary broad leaves when they grow on the land. The third effect of external conditions is seen when plants growing in new and unwonted conditions show a wide range of diversity, including many reversions and abnormalities. In such cases it is obvious that the new conditions have changed the expression of the characters, but it has also to be recognized that the changes are in the nature of disturbances of the normal expression of the characters rather than of new adjustments. Great diversity shows instead a lack of adjustment, each individual appearing to change in a different direction.

As might be expected, however, there are also intermediate stages between these three different effects. It is becoming apparent that the external conditions are not only able to call forth regular environmental adjustments, but are also able to induce somewhat regular changes of characters that have no direct connection with environmental needs.

Many plantings of Central American varieties of cotton in Texas have been rendered completely sterile through the exclusive development of vegetative branches from the axillary buds instead of fruiting branches, which arise from extra-axillary buds. This behavior may be viewed as an intensification of the vegetative tendency, which remains largely in abeyance when the plants develop in a normal manner, as they are able to do after a few seasons of acclimatization, that is, if the first plantings do not carry the vegetative intensification to the point of complete sterility.

A conspicuous example of a less violent form of intensification was observed at Del Rio, Tex., in 1907. The Parker variety of cotton showed a pronounced semicluster habit or shortening of the internodes of the fruit branches, a notable departure from the previous behavior of our stock of this variety, which had been under observation in several different localities in the preceding years. Apart from the fact that every precaution is taken to avoid mistakes in labeling and planting the seed, the possibility of error in this case seems to be entirely eliminated by the fact that six different selections of Parker were grown at Del Rio and that all of them behaved in the same manner with reference to this change in the lengths of the

fruiting branches. Plantings of the same strains from the same lots of seeds in several other localities in Texas in the same season produced no such results. In other places the cluster tendency was shown in only a few individual plants. We have therefore to admit that the conditions under which the plants developed at Del Rio brought about in some unknown manner a pronounced strengthening of the cluster tendency, which affected all the plantings in a notable manner. There seems to be no escape from the recognition of the fact that there are environmental intensifications of characters quite as pronounced in particular cases as those secured by hybridization, and more stable in their subsequent expression.

The indication that the conditions at Del Rio were responsible for the more pronounced cluster tendency of the Parker cotton was confirmed by the behavior of other varieties. Those that have the cluster tendency as a usual characteristic showed it in a pronounced manner. Many other long-limbed varieties showed individual plants more or less clustered, though no other long-limbed type changed to the cluster form with any such regularity as the Parker.

In the season of 1908 conditions at Del Rio did not show any general tendency to intensify the cluster habit more than at other places. A row of Parker cotton planted for the first time at Del Rio did not become clustered like that grown in 1907, only a single plant giving an indication of a tendency to shorten the internodes of the fruiting branches. In the rows raised from the Del Rio seed of the previous year there were also many plants that had fruiting branches of the normal length and showed no sign of semicluster parentage. But in a large proportion of the plants the cluster tendency was still obvious, though it was not expressed with any such regularity as in the preceding year, but in all stages, some less pronounced than before, some much more pronounced.

In a similar manner the Del Rio seed, when taken to other places and grown in comparison with other Parker stocks, gave obvious indications of a strengthened tendency to the cluster habit, though the clustering was expressed in different degrees in different places, evidently depending somewhat upon the luxuriance of the plants. The plants of 1907 at Del Rio which showed the cluster tendency with the greatest regularity were less than half the size of those of 1908, which may be considered as abnormally large, since they were inferior in yield and quality of lint. Nevertheless, it is not to be assumed that the cluster tendency is connected with mere reduction in size, for the plants of 1907 were well nourished and very fertile. Much smaller plants can be grown under unfavorable conditions without changing the proportions of the fruiting branches. The cluster characteristic is to be viewed rather as an intensification of

fertility, since in its extreme forms of expression it changes vegetative buds over into fruit buds and thus prevents the development of the fertile branches. The effect is to transform a broad, branching, tree-shaped plant into a tall, spikelike, "limbless" plant. My attention has been called by Prof. Edward L. Greene to indications of a similar transformation in a related plant, the common hollyhock, which several early European botanists figured as a branching plant of the same general form as cotton.

The same relation of the expression of the cluster tendency to external conditions has also been shown by a Mexican cotton. At Del Rio in 1907 two notably different forms of plants were found in the same row, one form characterized by shortened internodes, though also differing in other habits of growth as well as in the bolls, lint, and seeds. When the same stock was inspected afterwards at Victoria, no indication of the cluster habit could be found in any of the plants, but a careful examination of the lint and the seeds showed that both of the types which were so obviously different at Del Rio were really present at Victoria, and still distinguishable, though the fact would certainly not have been suspected without the previous attention to the more conspicuous differences which came into expression at Del Rio.

The behavior of the Del Rio semicluster selection of this Mexican stock in 1908 showed a very definite inheritance of the cluster tendency. At Del Rio, where the conditions were not so favorable for the expression of this characteristic as in the year before, it was still very apparent, and in other places it came into still stronger expression than at Del Rio. At Yuma there was an opportunity to compare the Del Rio semicluster selection with another selection made at Yuma from the same original Mexican stock for the same semicluster characteristic. The Del Rio selection notably excelled the Yuma selection in the expression of the cluster tendency, and also showed in many individuals a distinct exaggeration of the tendency beyond the stage shown at Del Rio in the previous year. Many branches were stopped by the production of flower buds after only three or four internodes had developed. As no such degree of clustering was noted in any of the Texas localities where this stock was grown, we may consider that the transfer to Yuma had the effect of still further intensifying the condition of expression attained at Del Rio in the previous year.

After such relations of external conditions to expression have been observed in unhybridized stocks it can no longer appear unreasonable to ascribe similar differences of expression among hybrids to external influences. Thus at Del Rio in 1908 a series of second-generation hybrids between the Kekchi cotton of Guatemala

and the Triumph Upland cotton were reported by Messrs. Argyle McLachlan and John H. Kinsler as showing many plants closely like Triumph. At Victoria, on the other hand, this same stock of hybrids produced only large bushy plants of the form familiar to us in unacclimatized conditions of the Kekchi. The contrast between plants of this kind and the normal form of the Triumph is very pronounced, for the Triumph has a curiously specialized habit of shortening a few of the fruiting branches near the base of the stalk.

This block of hybrids may be contrasted with the next, representing the second generation of the same Kekchi cotton crossed with the McCall Upland variety, which has normally a pronounced cluster habit. A majority of the plants had the same form as the Triumph hybrids, but many individuals were definitely clustered like the McCall grandparent. A census of the plants was made by Mr. McLachlan, who found 53 plants of the McCall type and 250 of the Kekchi, a proportion suggestive of Mendelism. Unfortunately, no count was made of the Del Rio plot of Triumph hybrids to see whether they gave any similar proportions, but the facts afford at least a suggestion that hybrids may be found which will show Mendelian proportions under some conditions, but not under others.

CONCLUSIONS.

When the diverse characters of cotton hybrids are compared with those of the parent groups, some of the parental characters are found to be intensified while others are suppressed. The same character or quality may be weakened or even completely suppressed in one series of hybrids and yet be increased or intensified in another, as shown by the behavior of the bractlets and the lint when the Kekchi cotton is crossed with Upland on the one hand and with Egyptian on the other.

In hybrids between the Kekchi cotton and United States Upland varieties the bractlets are suppressed and the lint shortened, while in hybrids between Kekchi and Egyptian cotton the bractlets are enlarged and the lint is notably improved in length and quality. In the first generation of the Egyptian hybrids the intensification of the characters which gives superiority to the lint is so regular that it may be possible to utilize it in the commercial production of high-grade fiber.

Suppression and intensification of characters are most pronounced in the first generation and tend to disappear in later generations. This fact stands in the way of the breeding of hybrid types with permanently intensified characters, but does not interfere with the commercial production of cotton from first-generation hybrids, if hybrid seed can be obtained in sufficient quantities.

It has become apparent in experiments that large proportions of hybrid seed can be obtained by planting two types of cotton close together and allowing the bees to cross-fertilize the flowers. It also appears practicable to raise fields of hybrid plants by sowing seed of Kekchi plants cross-fertilized with Egyptian pollen. The Kekchi seedlings can be easily recognized and removed, leaving only the hybrids to mature.

Such a method of producing cotton from first-generation hybrids is brought within the range of practicability in Arizona by the unusual abundance and activity of cross-fertilizing insects and by the dry climate, which enables the growth and fertility of the plants to be definitely controlled by careful irrigation. The superior quality of the hybrid cotton and the high prices it could command in the market will also justify the use of special methods of breeding and cultivation which would not be advisable in the production of a cheaper staple.

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